

Economic Long-Duration Electricity Storage by Using Low-Cost Thermal Energy Storage and High-Efficiency Power Cycle (ENDURING)

Project Vision

- To create an innovative LDES system and a fluidized bed heat exchanger design.
- To develop components meeting the cost and performance targets, and a commercial path.
- To provide electricity for several days with low-cost particle thermal energy storage.

Principal Investigator

- Dr. Zhiwen Ma (NREL)

Team Members

- GE Global Research (GE-GRC)
- Purdue University (PU)
- POWER Engineers (PEI)
- Allied Mineral Products, Inc. (Allied)
- Colorado School of Mines (CSM)

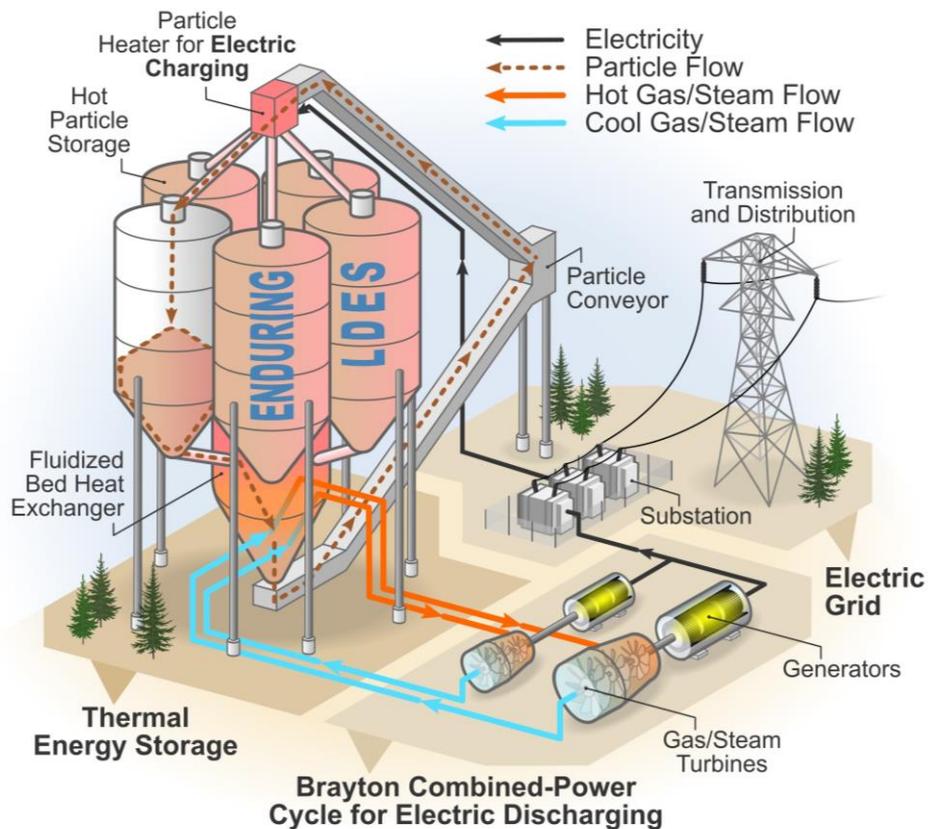
Total project cost

\$3.235 MM

Project length

36 months

ENDURING Long Duration Energy Storage (LDES)



Technology Innovations

- ENDURING LDES operates as a standalone thermal battery for grid-scale electricity storage.
- Inexpensive, stable, abundant solid particles as storage media.
- Novel fluidized bed heat exchanger for cost-effective and efficient power conversion.
- Decoupled power and storage duration.
- Scalable system for wide storage capacity (10 – 100 hours) and power (60 – 300 MWe).

ENDURING Project Team



NREL is specialized in thermal energy storage in concentrating solar power (CSP):

- Early advocacy of the supercritical carbon dioxide (sCO₂) Brayton power cycle.
- SunShot projects using particles as heat transfer fluid and storage media.



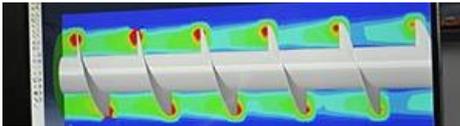
GE Global Research (GE-GRC) will lead the power system integration:

- Global leader in power system equipment and services.
- Record power conversion efficiency of gas-turbine combined cycles.

ENDURING Project Team



Colorado School of Mines (CSM) participated in NREL's SunShot project in TES and particle system.



Purdue Center for Particulate Products and Processes has full line of particle characterization equipment, and expertise in MFIx modeling.



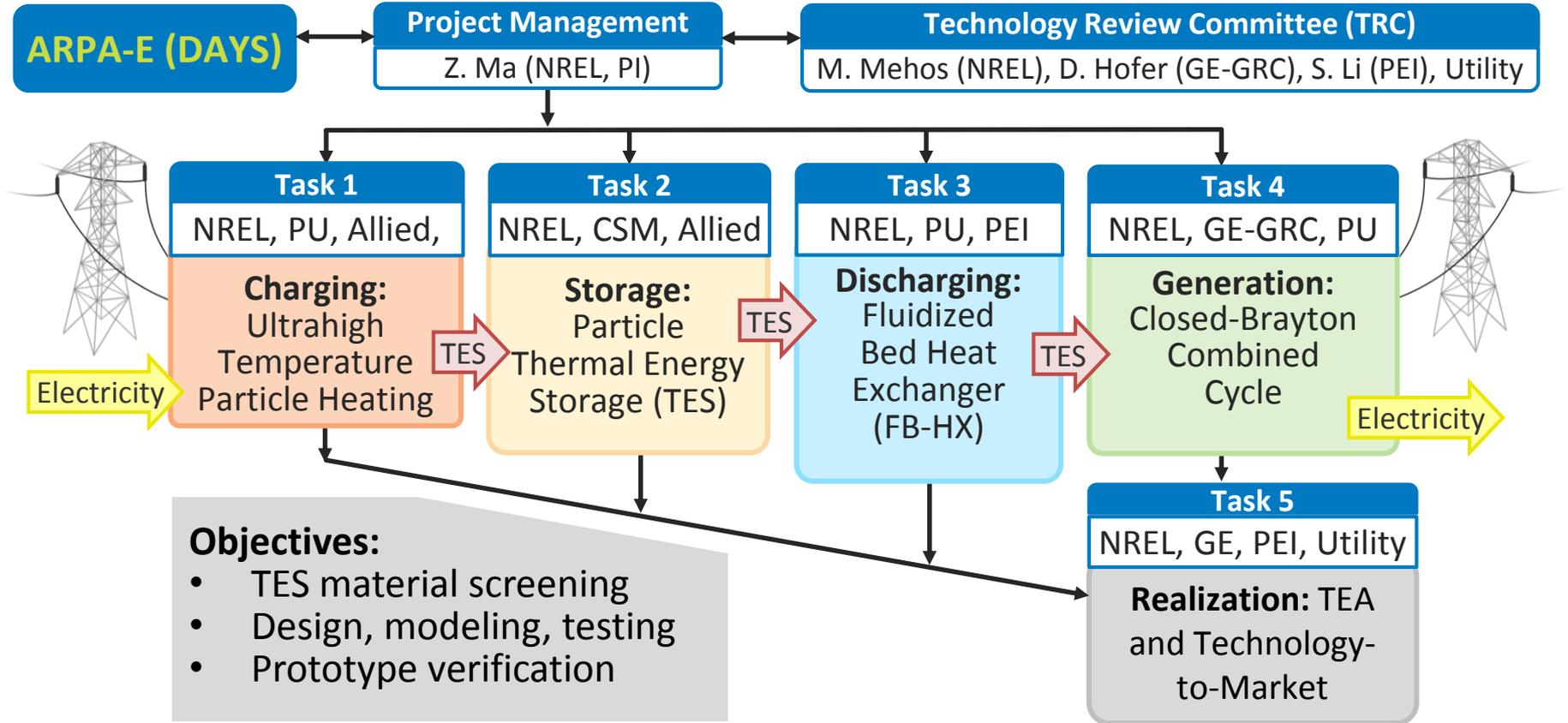
POWER Engineers (PEI):

- Power system integration
- Power generation engineering



Allied is specialized in refractory materials, powder, high-temperature insulation ($>1,600^{\circ}\text{C}$) material, design and construction.

Tasks and Team Roles



Project Objectives and Timeline

Private/public partners for commercialization

Technology Transfer & Outreaching (TTO)

- Utility involvement
- EPCs, manufacturing
- Supply chains

Demonstration:
Pilot plant in 2 – 5 MW

- 2–5 MW heater and fluidized bed
- 10–50 MWh pilot storage design
- 1 – 2 MW turbine integration

ARPA-E DAYS

BP2 Development:
Concept verification laboratory prototypes

- 10 kW benchtop particle heater
- 5 kW fluidized bed gas/particle test prototype
- 100 kWh TES material and design verification

BP1 Research:
Fundamental designs and materials

- Select particles, heater, storage insulation, containment
- Fluidized bed, gas seal, particle feeding and dispensing
- Power system configuration, efficiency, cycle optimization

2019

2020

2021

2022

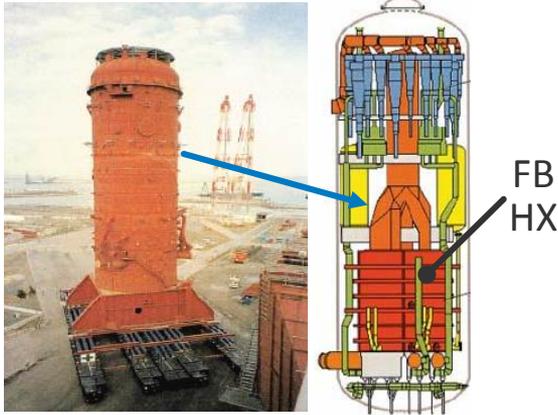
2023

2024

Challenges and Risk Mitigation



Commercial 360-MW FB boiler



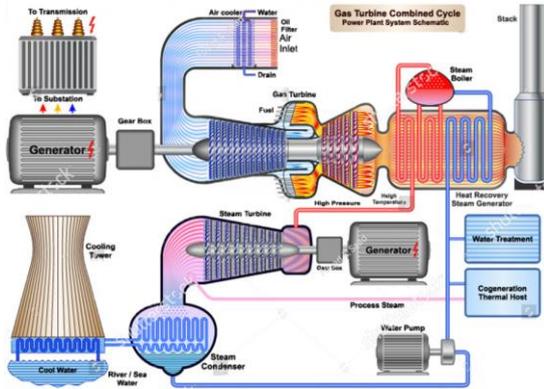
1. Particle stability at 1,200°C

- Knowledge/resources from Allied Mineral, Purdue Center for Particulate Products and Processes, and particle suppliers will be applied.
- Several particle types will be screened/tested.

2. Fluidized Bed (FB) Heat Exchanger (HX) design

- Strong team expertise on gas/solid two-phase flow modeling, testing, and scaling up will be tapped.
- Industry experiences and commercialized technologies will be leveraged.

Challenges and Risk Mitigation



Leveraging a power plant



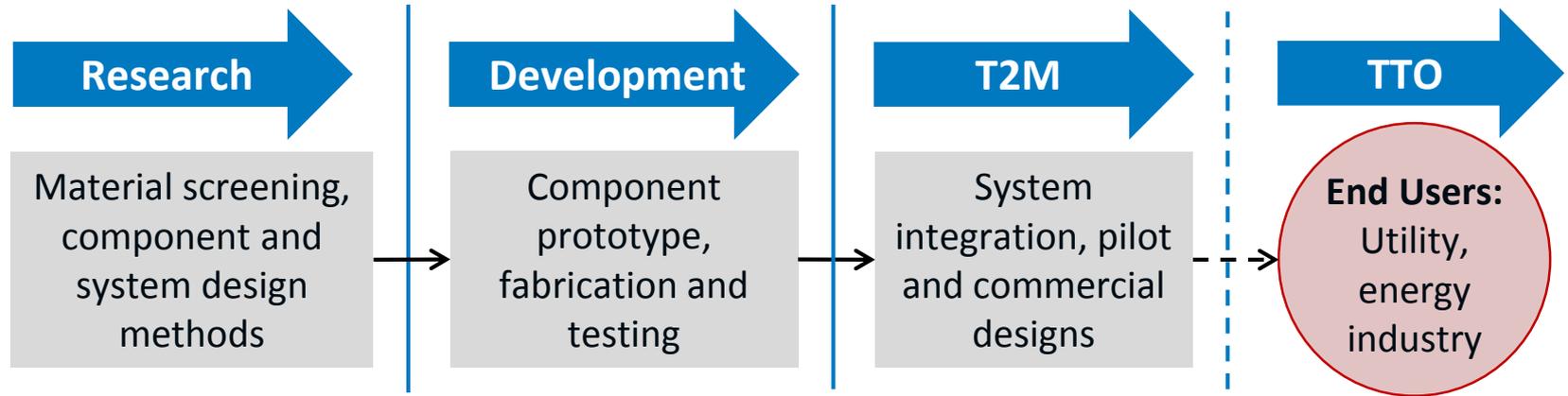
3. Working fluid and particle interaction:

- Material stability verification in the lab test.
- Power configuration selection between closed and open Brayton combined cycles.
- GE's expertise in gas-turbine combined cycle.

4. LDES system cost to meet the LCOS target:

- Initially leverage the infrastructure and equipment of a retired thermal power plant.
- Optimize a power system for high-efficiency options and standardize a design.
- Develop an ecosystem of low cost suppliers.

Commercialization Path and Strategy



1. Make connections with utilities, ventures, and commercialization partners.
2. Serve California, Colorado, and other states for their carbon-free energy goals.
3. Outreach material suppliers, supply chains, and component manufacturers.
4. Expand the storage applications to other energy industries, nuclear power.
5. Participate in energy storage communities: ASME, IEEE, POWERGEN, media, etc.

Thank you

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- <https://atainsights.com/recordings-and-presentations-how-to-design-and-build-cost-competitive-thermal-storage-tes-variable-renewable-vre-projects/>
- Frontiers in Energy Research topic on long duration energy storage